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(54) **Tyre with improved tread**

(57) Tyre (10) comprising a tread portion designed to be worn off during the life of the tyre having a radial thickness T, an outer edge (45) and an inner edge (46), the axial distance between the outer edge (45) and the inner edge (46) defining the axial width L of the tread, the tread comprising four adjacent portions (411-414) made of a four rubber compounds, wherein the rubber compounds making up the first and third portions are predominantly filled with carbon black filler, wherein the rubber compounds making up the second and fourth portion are predominantly filled with non carbon black filler, wherein the rubber compounds making up the first and third portions have a value for tanδ at 0°C, at a stress of 0.7 MPa, that is lower than that of the rubber compounds making up the second and fourth portion, and wherein the axial width of the first portion decreases and the axial width of the second portion increases as a function of the distance from the rolling surface of the tread when unworn.

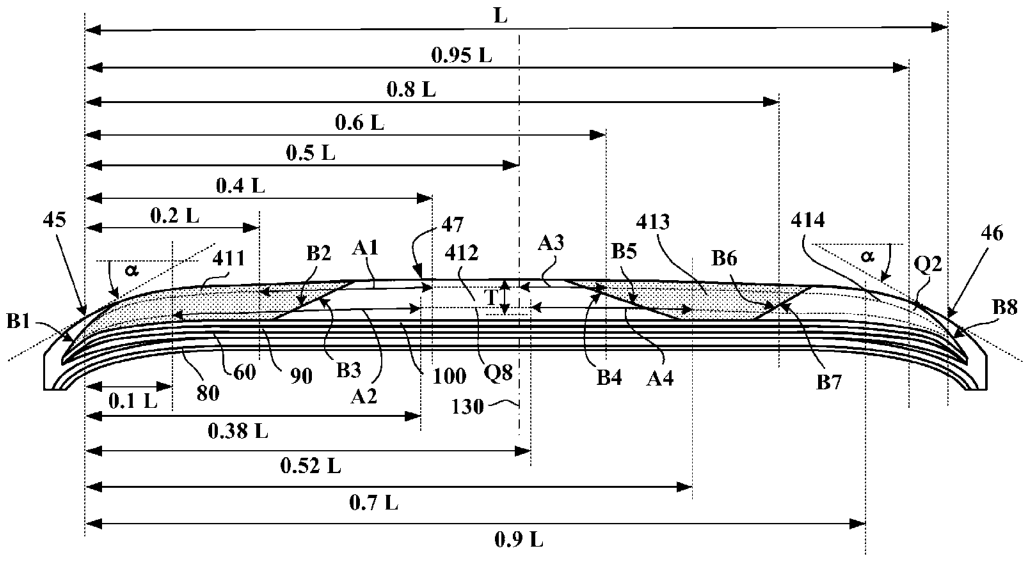

FIG. 12

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to tyres for passenger vehicles. It relates more particularly to tyres suited to sporty road driving.

BACKGROUND

[0002] The grip that tyres have on the ground on which they are rolling is one of the most important features from the point of view of the safety of the driver of a vehicle fitted with tyres. It is also of key importance in determining the performance of the vehicle in sporty road driving. If its tyres lose their ability to steer as a result of a lack of grip, the vehicle can no longer be steered.

[0003] Of course, a vehicle, even if designed for sporty use, has to be driven in variable weather conditions. It is, therefore, a known practice for the tyre to be provided with means that provide good grip on dry ground and on wet ground. In particular, it is possible to adapt at least part of the tread pattern to use on wet ground, for example by providing recesses able to drain away and/or to store water, or by increasing the number of tread pattern edges able to cut through the film of water formed between the tread and the ground. It is also possible to vary the materials of which the tread is made, using rubber compounds more particularly suited to use on wet ground and/or on dry ground. A tread comprising the two types of rubber compound is able to achieve good grip under all circumstances. An example of such a tyre is given in document EP 1 308 319.

[0004] Under sporty road driving conditions, the tyres of a vehicle experience substantial transverse stresses when the vehicle fitted with the tyres is cornering. During the corner, the transverse stresses cause, on the contact area where each tyre makes contact with the ground on which it is rolling, deformation resulting in a substantially trapezoidal shape. The side of the contact area which is furthest away from the centre of the bend lengthens, while the side of the contact area closest to the centre of the bend shortens.

[0005] The "side of the contact area furthest from the centre of the bend" is the side via which the elements of the tread come into contact with the ground in the direction of the rate of drift of the centre of the wheel on which the tyre is mounted. For this reason, it is sometimes referred to as "(transverse) leading edge". The opposite side, that is to say the "side of the contact area closest to the centre of the bend" is sometimes referred to as the "(transverse) trailing edge".

[0006] This "trapezoidal" deformation alters both the load borne by the various ribs of the tread and the contribution that each makes to the transverse force developed by the tyre. For a given load that the tyres of the vehicle have to support in a given cornering situation, the ribs that have become lengthened bear a greater share of the total load borne by the tyre. The ribs which have shortened bear a correspondingly lower proportion of the total load borne by the tyre. For a given transverse force, delivered by one of the tyres in a given cornering situation, it follows that the most heavily loaded ribs (in general, those on the side furthest from the centre of the bend) are those which make the greatest contribution to the total transverse force.

[0007] Rubber compounds suited for use on wet ground are generally more fragile with respect to the very high thermal and mechanical stresses generated in the contact area of a tyre under severe cornering conditions on a dry road surface. If the tread of the tyre is provided with portions made of a rubber compound with better grip on dry ground and with portions made of a rubber compound with better grip on wet ground, then it is preferable to ensure that the rubber compound that has better grip on dry ground is placed on the side of the contact area that is furthest from the centre of the bend. Thus, even if the contact area becomes trapezoidal, the tyre will maintain good grip on dry ground, that is to say a good ability to develop a high transverse force. Further, because the ground contact pressures are higher on this same side of the contact area (which is the furthest from the centre of the bend), the drainage of the water with which the road surface is wetted is generally rather satisfactory in this part of the contact area. As a consequence, conditions that establish good grip contact and that allow use of a rubber compound with better grip on dry ground are created in this region of the tread. In other words, the tyre, in this region, behaves as if it were rolling on dry ground. There is therefore no need to provide in this part of the tread a rubber compound that has better grip on wet ground and of which the performance on dry ground is inferior than that of a rubber compound that has better grip on dry ground. The "Pilot Sport 2" tyre commercialised by Michelin is an example of a tyre that has such a distribution of rubber compounds within its tread.

[0008] In spite of the good performance offered by this tyre in terms of grip, there is still an increasing need to improve the compromise between grip on dry ground and grip on wet ground of tyres, and more particularly of tyres designed for sporty road driving.

SUMMARY OF THE INVENTION

[0009] One of the objectives of the present invention is, therefore, to provide a tyre that provides a better compromise between grip on dry ground and grip on wet ground, both when the tyre is new (unworn) or almost new and when the tyre has undergone significant wear.

[0010] This objective is achieved using a tyre that has a predetermined direction of mounting, in which a portion of that part of the tread that is traditionally reserved for the rubber compounds that have better grip on wet ground is made of a rubber compound that has better grip on dry ground. In other words, a portion of that part of the tread that is situated on that side of the vehicle which faces toward the vehicle when the tyre is mounted on the vehicle in said predetermined direction of mounting (that is to say on the "inside" of the tyre; the corresponding sidewall commonly bearing the inscription "inside" and/or the opposite sidewall commonly bearing the inscription "outside") is made of a rubber compound that has better grip on dry ground. The compromise between grip on dry ground and grip on wet ground is optimised as a function of tyre wear by astutely changing the axial extent of portions of the tread portions made from rubber compound that has better grip on dry ground.

[0011] More specifically, the objective is achieved by using a tyre designed to be mounted on a mounting rim of a wheel of a vehicle and having a predetermined direction of mounting on the vehicle, wherein the tyre comprises a tread having a rolling surface designed to come into contact with a ground when the tyre is rolling on the ground, and a tread portion designed to be worn off during the life of the tyre, this tread portion having a radial thickness T. The tread, when unworn, has an outer edge and an inner edge, the outer edge being situated on that side of the tyre which, when the tyre is mounted on the vehicle in said predetermined direction of mounting, faces toward the outside of the vehicle, the inner edge being situated on that side of the tyre which, when the tyre is mounted on the vehicle in said predetermined direction of mounting, faces toward the vehicle. The axial distance between the outer edge and the inner edge defines the axial width L of the tread.

[0012] The tread comprises, in any radial section, a first portion made of at least one first rubber compound, wherein the first portion extends from a first axial boundary position to a second axial boundary position. The axial distance of this first axial boundary position from the inner edge is greater than or equal to 95% of the of the axial width L of the tread.

[0013] The tread further comprises, in any radial section, a second portion that is axially adjacent to the first portion and made of at least one second rubber compound. The second portion extends from a third axial boundary position to a fourth axial boundary position.

[0014] According to a particular embodiment, said third axial boundary position coincides with said second axial boundary position, at least for some values of DR, or even for all values of DR. According to another embodiment, said third axial boundary position and said second axial boundary position delimit an incision in the tread which separates said first and second portions of the tread.

[0015] The tread further comprises, in any radial section, a third portion that is axially adjacent to the second portion and made of at least one third rubber compound. The third portion extends from a fifth axial boundary position to a sixth axial boundary position, wherein the axial distance between the sixth axial boundary position and the outer edge is greater than or equal to 80% and smaller than or equal to 90% of the axial width L of the tread for DR = 0.2-T, where DR is the radial distance from the rolling surface of the unworn tread.

[0016] According to a particular embodiment, said fifth axial boundary position coincides with said fourth axial boundary position, at least for some values of DR, or even for all values of DR. According to another embodiment, said fifth axial boundary position and said fourth axial boundary position delimit an incision in the tread which separates said second and third portions of the tread.

[0017] Finally, the tread comprises, in any radial section, a fourth portion that is axially adjacent to the third portion and made of at least one fourth rubber compound. The fourth portion extends from a seventh axial boundary position to an eighth axial boundary position, the axial distance of said eighth axial boundary position from the outer edge being greater than or equal to 95% of the of the axial width L of the tread.

[0018] According to a particular embodiment, said seventh axial boundary position coincides with said sixth axial boundary position, at least for some values of DR, or even for all values of DR. According to another embodiment, said seventh axial boundary position and said sixth axial boundary position delimit an incision in the tread which separates said third and fourth portions of the tread.

[0019] The first, second, third and fourth portions extend over the entire circumference of the tyre and have an intersection with the rolling surface when the tyre is new or, at the latest, when the tread wear has reached 10%.

[0020] Said at least one first rubber compound and said at least one third rubber compound contain at least one elastomer and at least one reinforcing filler containing a carbon black, the carbon black representing a percentage PN1 greater than or equal to 50% and less than or equal to 100% of the weight of all of the reinforcing filler, and wherein said at least one second rubber compound and said at least one fourth rubber compound contain at least one elastomer and at least one reinforcing filler, possibly including a carbon black, the carbon black representing a percentage PN2 greater than or equal to 0% and less than or equal to 50% of the weight of all of the reinforcing filler.

[0021] Said at least one first rubber compound and said at least one third rubber compound have a value for tanδ at 0°C, at a stress of 0.7 MPa, that is lower than that of said at least one second rubber compound and said at least one fourth rubber compound.

[0022] In a tyre according to the invention, at least one of the following conditions (C1) and (C2) is met:

[0023] Condition (C1) : the first portion has, in any radial section, an axial width that decreases as a function of the radial distance DR from the rolling surface of the unworn tread, the second axial boundary position varying as a function of the radial distance DR, such that the axial distance between the second axial boundary position and the outer edge is greater than or equal to 20% and smaller than or equal to 40% of the axial width L of the tread for DR = 0.2·T, and greater than or equal to 10% and smaller than or equal to 38% of the axial width L of the tread for DR = 0.8·T, provided that the second axial boundary position for DR = 0.2·T is axially inside by at least 2% of the axial width L of the tread with respect to the second axial boundary position for DR = 0.8·T.

[0024] Condition (C2) : the second portion has, in any radial section, an axial width that increases as a function of the radial distance DR from the rolling surface of the unworn tread, the fourth axial boundary position varying as a function of the radial distance DR, such that the axial distance between the fourth axial boundary position and the outer edge is greater than or equal to 50% and smaller than or equal to 60% of the axial width L of the tread for DR = 0.2·T, and greater than or equal to 52% and smaller than or equal to 70% of the axial width L of the tread for DR = 0.8·T, provided that the fourth axial boundary position for DR = 0.2·T is axially inside by at least 2% of the axial width L of the tread with respect to the fourth axial boundary position for DR = 0.8·T.

[0025] Preferably, both conditions (C1) and (C2) are met simultaneously.

[0026] In a tyre according to the invention, the axial width of the first portion having relatively good grip on dry ground decreases and the axial width of the second portion having better grip on wet ground increases as the tread wears off. This is advantageous because as the tread wears off, aquaplaning phenomena become more problematic (water storage and evacuation become more difficult when the depth of the incisions in the tread diminishes), whereas the tyre grip on dry ground does not significantly change with tyre wear. In a tyre according to the invention, therefore, the relative part - in the rolling surface - of rubber compounds having better grip on wet ground increases when the tyre wears off and the overall tyre grip compromise is improved, and this allows to have both better performance at low speed (where aquaplaning does not appear) and quicker recovery after aquaplaning thanks to the greater part of compound having better grip on wet ground.

[0027] According to one advantageous embodiment, said portions made of said at least one first, second, third and fourth rubber compounds all have an intersection with the rolling surface when the tyre is new. Thus, the tyre is able to develop its full potential right from first use.

[0028] According to another advantageous embodiment, said sixth axial boundary position varies as a function of the radial distance DR from the rolling surface of the unworn tread, such that the axial distance of the sixth axial boundary position from the outer edge is greater or equal to 70 % and smaller or equal than 95% of the axial width L of the tread for DR = 0.8·T, provided that the difference between (a) the sixth axial boundary position for DR = 0.2·T and (b) the sixth axial boundary position for DR = 0.8·T, is greater than or equal to 2% of the axial width L of the tread.

[0029] According to yet another advantageous embodiment, said at least one third rubber compound is identical to said at least one first rubber compound and said at least one fourth rubber compound is identical to said at least one second rubber compound. This embodiment has the notable advantage of simplifying the manufacture of the tyre and the control of stocks of rubber compound at the factory.

[0030] According to a fourth advantageous embodiment, said at least one first rubber compound and said at least one third rubber compound have a value for tanδ at 10°C, at a stress of 0.7 MPa, that is higher (preferably higher by at least 0.05) than that of said at least one second rubber compound and said at least one fourth rubber compound. As a matter of fact, the value tanδ of the rubber compound at 10°C, at a stress of 0.7 MPa, neatly characterizes the grip on dry ground.

[0031] According to another advantageous embodiment, the difference between the value of tanδ for said at least one first rubber compound and said at least one second rubber compound is greater than or equal to 0.05, wherein the difference between the value of tanδ for said at least one second rubber compound and said at least one third rubber compound is greater than or equal to 0.05, and wherein the difference between the value of tanδ for said at least one third rubber compound and said at least one fourth rubber compound is also greater than or equal to 0.05. This applies to both the tanδ values at 0°C and the tanδ values at 10°C, as the case may be.

[0032] Of course, it is possible, and even desirable to combine two or more of the embodiments described.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] Figure 1 depicts a tyre according to the prior art.

[0034] Figure 2 depicts a partial perspective view of a tyre according to the prior art.

[0035] Figure 3 depicts, in radial cross section, a quarter of a tyre according to the prior art.

[0036] Figures 4 and 5 illustrate how the axial edge of a tread is determined.

[0037] Figure 6 illustrates the terms "inner edge" and "outer edge" of a tread.

[0038] Figure 7 schematically depicts the crown of a tyre according to the prior art.

[0039] Figure 8 schematically depicts the deformation of a tyre according to the prior art when it experiences substantial transverse stresses.

[0040] Figure 9 illustrates the trapezoidal distortion of the contact area of such a tyre.

[0041] Figures 10 and 11 illustrate the trapezoidal distortion of the contact area of two tyres mounted on one and the same axle of a vehicle, depending on the direction in which the vehicle is cornering.

[0042] Each of figures 12 to 18 schematically depicts the crown of a tyre according to an embodiment of the invention.

[0043] Figure 19 illustrates the notion of the radial thickness of the tread portion to be worn off during the life of the tyre.

DETAILED DESCRIPTION OF THE DRAWINGS

[0044] When using the term "radial" it is appropriate to make a distinction between various different uses that the person skilled in the art makes of this word. Firstly, the expression refers to a radius of the tyre. It is in that sense that a point P1 is said to be "radially inside" a point P2 (or "radially on the inside of" the point P2) if it is closer to the axis of rotation of the tyre than is the point P2. Conversely, a point P3 is said to be "radially outside" a point P4 (or "radially on the outside of" the point P4) if it is further from the axis of rotation of the tyre than is the point P4. Progress "radially inward (or outward)" will mean progress toward smaller (or larger) radii. In terms of radial distances, it is this sense of the word that applies also.

[0045] By contrast, a thread or a reinforcement is said to be "radial" when the thread or the reinforcing elements of the reinforcement make an angle greater than or equal to 80° and less than or equal to 90° with the circumferential direction. Let us specify that in this document, the term "thread" is to be understood in a very general sense of the word and encompasses threads in the form of monofilaments, multifilaments, a cord, a yarn or an equivalent assembly, irrespective of the material of which the thread is made or of the surface treatment it has undergone to enhance its bonding with the rubber.

[0046] Finally, a "radial cross section" or "radial section" here means a cross section or a section on a plane which contains the axis of rotation of the tyre.

[0047] An "axial" direction is a direction parallel to the axis of rotation of the tyre. A point P5 is said to be "axially inside" a point P6 (or "axially on the inside of" the point P6) if it is closer to the median plane of the tyre than is the point P6. Conversely, a point P7 is said to be "axially outside" a point P8 (or "axially on the outside of" the point P8) if it is further from the median plane of the tyre than is the point P8. The "median plane" of the tyre is the plane which is perpendicular to the axis of rotation of the tyre and which lies equal distances from the annular reinforcing structures of each bead.

[0048] Two portions A and B of the tread are said to be "axially adjacent" if there is at least one axial direction D connecting a point P1 of portion A and a point P2 of portion B so that the segment of direction D connecting points P1 and P2 does not intersect any portion of the tread other than portions A and B. The segment of direction D connecting points P1 and P2 may, however, have an intersection with an incision (groove, sipe, ...) separating portions A and B of the tread without this being detrimental to A and B being considered to be "axially adjacent". In other words, two axially adjacent portions are positioned axially side by side, either in direct contact or separated by incisions only (but not by other tread portions).

[0049] A "circumferential" direction is a direction perpendicular both to a radius of the tyre and to the axial direction. A "circumferential section" is a section on a plane perpendicular to the axis of rotation of the tyre.

[0050] Two reinforcing elements are said to be "parallel" in this document when the angle formed between the two elements is less than or equal to 20°.

[0051] What is meant here by "rolling surface" is all the points on the tread of a tyre that come into contact with the ground when the tyre is rolling.

[0052] The expression "rubber compound" denotes a compound of rubber containing at least one elastomer and one filler.

[0053] "Wear level" of a tyre tread means the ratio between the radial thickness that the tread has lost due to wear and the radial thickness of the tread portion that the tread is intended to lose before having to be changed or retreaded. In most tyres there are wear indicators provided at the bottom of grooves that indicate that the tread has lost all the thickness it is intended to lose before replacement, so that it becomes apparent that the tyre has to be changed or retreaded. A wear level of 25% means that the tread has lost a quarter of the rubber composition that can be worn away before changing (or retreading) becomes necessary. The wear level is generally expressed as a percentage; at a given moment not all the zones of the tread necessarily have the same wear level ("uneven wear").

[0054] The "radial thickness T" of the tread portion designed to be worn off during the life of the tyre is determined as follows. For each axial position, one considers the radial depth PR (in mm) of the deepest incision that is found over the circumference of the tyre - the radial thickness T at this axial position (in mm) is defined to be PR-1.6. This is because there are regulations that require a tyre to have a minimum incision depth of 1.6 mm. If, for a given axial position, there is no incision over the whole circumference of the tyre but there are axial positions on both sides (axially) of the axial position under consideration where incisions are found, then the radial thickness at the axial position under consideration is defined to be the interpolated thickness of the closest axial positions on both sides where there are incisions. If, for a given axial position, there is no incision over the whole circumference of the tyre but there are axial positions axially inside the axial position under consideration where incisions are found, then the radial thickness at the axial position under consideration is defined to be identical to thickness of the closest axial positions axially inside it where there are incisions. See also figure 19.

[0055] Obviously, there is a direct link between the wear level and the radial thickness T of the tread portion designed to be worn off during the life of the tyre. Locally, a wear level of X% is reached when X% of the thickness T have been worn off.

[0056] To make the description of the variants shown with the figures easier to read, the same references are used to denote elements that have identical structures.

[0057] Figure 1 schematically depicts a tyre 10 according to the prior art. The tyre 10 comprises a crown comprising a crown reinforcement (not visible in Figure 1) surmounted by a tread 40, two sidewalls 30 extending the crown radially inward, and two beads 20 radially inside of the sidewalls 30.

[0058] Figure 2 schematically depicts a partial perspective view of a tyre 10 according to the prior art and illustrates the various components of the tyre. The tyre 10 comprises a carcass reinforcement 60 made up of threads 61 coated with rubber compound, and two beads 20 each comprising annular reinforcing structures 70 which hold the tyre 10 on the rim (not depicted). The carcass reinforcement 60 is anchored in each of the beads 20. The tyre 10 further comprises a crown reinforcement comprising two plies 80 and 90. Each of the plies 80 and 90 is reinforced with thread-like reinforcing elements 81 and 91 which are parallel within each layer and cross from one layer to the next, making angles ranging between 10° and 70° with the circumferential direction. The tyre further comprises a hooping reinforcement 100, arranged radially on the outside of the crown reinforcement, this hooping reinforcement being formed of circumferentially directed spiral-wound reinforcing elements 101. A tread 40 is laid on the hooping reinforcement; it is this tread 40 that provides contact between the tyre 10 and the road surface. The tyre 10 depicted is a "tubeless" tyre: it comprises an "inner liner" 50 made of a rubber compound impervious to the inflation gas, covering the interior surface of the tyre.

[0059] Figure 3 schematically depicts, in radial cross section, one quarter of a reference tyre 10 of the "Pilot Sport 2" type commercialised by Michelin. The tyre 10 comprises two beads 20 designed to come into contact with a mounting rim (not depicted), each bead 20 comprising a plurality of annular reinforcing structures 70. Two sidewalls 30 extend the beads 20 radially outward and meet in a crown 25 comprising a crown reinforcement formed of a first layer of reinforcing elements 80 and of a second layer of reinforcing elements 90, and radially surmounted by a hooping reinforcement 100, which is itself radially surmounted by a tread 40. The median plane 130 of the tyre is also indicated.

[0060] The way in which the axial edges of a tread are determined is illustrated in Figures 4 and 5 each of which shows the profile of a portion of the tread 40 and of that part of the sidewall 30 that is adjacent to it. In some tyre designs, the transition from tread to sidewall is clear-cut, as in the case depicted in Figure 4, and determining the axial edge 45 of the tread 40 is straightforward. However, there are tyre designs in which the transition between tread and sidewall is continuous. An example is given in Figure 5. The edge of the tread is then determined as follows. The tangent to the rolling surface of the tyre at any point on the rolling surface in the region of transition toward the sidewall is drawn onto a radial cross section of the tyre. The axial edge is the point at which the angle α (alpha) between said tangent and an axial direction is equal to 30°. When there are several points at which the angle α (alpha) between said tangent and an axial direction is equal to 30°, it is the radially outmost point that is adopted. In the case of the tyre depicted in Figure 3, the axial edge 45 has been determined in this way. Whenever axial edges of the tread are referred to herein, what is meant are the axial edges of the tread when unworn.

[0061] Each layer of reinforcing elements 80 and 90 comprises thread-like reinforcing elements, coated in a matrix formed of rubber compound. The reinforcing elements of each layer are substantially mutually parallel; the reinforcing elements of the two layers cross from one layer to the next at an angle of about 20°, as is well known to those skilled in the art for tyres known as radial tyres.

[0062] The tyre 10 further comprises a carcass reinforcement 60 which extends from the beads 20 through the sidewalls 30 as far as the crown 25. This carcass reinforcement 60 here comprises thread-like reinforcing elements that are directed substantially radially, that is to say that make an angle greater than or equal to 80° and less than or equal to 90° with the circumferential direction.

[0063] The carcass reinforcement 60 comprises a plurality of carcass reinforcing elements; it is anchored in the two beads 20 between the annular reinforcing structures 70.

[0064] Figure 7 schematically depicts the crown of a tyre designed to be mounted on a mounting rim of a wheel of a vehicle and having a predetermined direction of mounting on the vehicle. The tyre comprises a tread having a rolling surface 47 designed to come into contact with the ground (not depicted) when the tyre is rolling on a ground, and a tread portion designed to be worn off during the life of the tyre, this tread portion having locally a radial thickness T. The tread, when unworn, has an outer edge 45 and an inner edge 46, the outer edge being situated on that side of the tyre which, when the tyre is mounted on the vehicle in said predetermined direction of mounting, faces toward the outside of the vehicle (see figure 6). The inner edge being situated on that side of the tyre which, when the tyre is mounted on the vehicle in said predetermined direction of mounting, faces toward the vehicle (see figure 6). The axial distance between the outer edge (45) and the inner edge (46) defines the axial width L of the tread.

[0065] The tread comprises a first portion 411 made of a first rubber compound, wherein the first portion extends from a first axial boundary position B1 to a second axial boundary position B2, and a second portion 412 that is axially adjacent to the first portion 411 and made of a second rubber compound. The second portion extends from the second axial boundary position B2 to a third axial boundary position B3 that is close to the inner edge 46. The first axial boundary position B1 and the third axial boundary position B3 vary slightly as a function of the radial distance DR from the rolling surface 47 whereas the second axial boundary position B2 does not vary as a function of the radial distance DR: the axial distance between the second axial boundary position B2 and the outer edge 45 is equal to 40% of the axial width L of the tread for all values of DR between DR = 0 and DR = T. The first portion 411 and the second portion 412 both have an intersection with the rolling surface 47 when the tyre is new (unworn). The second rubber compound has a grip on wet ground that is superior to the grip on wet ground of the first rubber compound, and a grip on dry ground that is inferior to the grip on dry ground of the first rubber compound.

[0066] Figures 8 and 9 schematically depict the deformation of a tyre 10 according to the prior art, inflated to 3 bar and heavily loaded (load of 7100 N) when it experiences substantial transverse stresses (camber: -4.4°, rate of sideslip: 3 m/s). Figure 8 corresponds to a view in the direction of forward travel of the tyre. The reference 2 indicates the axis of rotation of the tyre 10 and the reference 3 the ground on which the tyre 10 is rolling.

[0067] Figure 9 depicts the footprint of the tyre 10 on the ground 3. To a first approximation, this footprint is in the shape of a trapezium 4 the long side 5 of which is the side furthest from the centre of the bend being taken by the vehicle on which the tyre 10 is mounted. Because the grip of the tyre is greater on dry ground than on wet ground, the transverse forces that the tyre may experience are also greater on dry ground and the trapezoidal deformation is more pronounced. It is, therefore, advantageous to ensure that the portion of rubber compound with better grip on dry ground is on that side of the contact area that is furthest from the centre of the bend, as is the case in the tyre depicted in Figure 7. By providing a portion made of rubber compound with better grip on wet ground on that side of the contact area that is closest to the centre of the bend, an advantageous compromise can be reached between the grip of the tyre on dry ground and on wet ground.

[0068] In defining a tyre according to the invention, a distinction has been made between that side of the tyre which, when the tyre is mounted on the vehicle in its predetermined direction of mounting, faces toward the outside of the vehicle, and that side of the tyre that faces toward the vehicle when the tyre is mounted on the vehicle in its predetermined direction of mounting. In the previous paragraph, by contrast, the physical effects have been explained with reference to the sides furthest from and closest to the centre of the bend. Of course, these distinctions do not correspond to one another, because reference to the centre of the bend depends on the direction of the bend (whether the vehicle is cornering to the left or to the right) whereas the side facing toward the outside of the vehicle and the side facing in toward the vehicle do not depend on this. This apparent difficulty may be explained using Figures 10 and 11.

[0069] Figure 10 illustrates the trapezoidal deformation of the contact area of two tyres 11 and 12 mounted on one and the same axle 7 of a vehicle, viewed upward from the ground on which the tyres are rolling. The case being considered is a left-hand bend (when considered from the point of view of the driver of the vehicle), that is to say a bend in the direction indicated using the arrow 151. The tyres 11 and 12 have been mounted in their predetermined directions of mounting: the inner edges 46 of their treads are on the side facing in toward the body of the vehicle (the body is not depicted), and the outer edges 45 facing toward the outside of the vehicle. Strictly speaking, the situation is optimized only for the tyre 11 because the rubber compound with better grip on dry ground, which is on the outer edge 45 side, is on the side furthest from the centre of the bend. By contrast, for the tyre 12, the rubber compound with better grip on dry ground is on the side closest to the centre of the bend. As has been depicted in Figure 11, the situation reverses when the driver corners to the right (from his point of view) that is to say in the direction indicated using the arrow 152. In figure 11 it is the tyre 12 that is best suited. Whatever the direction of the bend, there is always one tyre that "does not suit". Because an ordinary vehicle corners as often to the left as to the right, it is none the less preferable to favour the tyre that is on the side furthest from the centre of the bend, because it is that tyre which bears more load and has the greater contact area. It is that tyre which, therefore, plays a dominant part in the overall grip of the vehicle. Therefore, such an arrangement corresponds to an advantageous compromise for vehicles that corner as often to the right as to the left. In n the infrequent case of a vehicle that turns always in the same direction (for example a vehicle that is exclusively used to cover a circular circuit in just one direction), it would be possible to optimize the mounting of the tyres to ensure that the rubber compound with the better grip on dry ground is always on the side furthest from the centre of the bend.

[0070] The invention provides a way to improve the overall grip performance still further and, more particularly, to improve the compromise between grip on dry ground and grip on wet ground, both when the tyre is new (unworn) or almost new and when the tyre has undergone significant wear. This objective is achieved using a tyre that has a predetermined direction of mounting, in which a portion of that part of the tread that is traditionally reserved for the rubber compounds that have better grip on wet ground is made of a rubber compound that has better grip on dry ground. In other words, a portion of that part of the tread that is situated on that side of the vehicle which faces toward the vehicle when the tyre is mounted on the vehicle in the predetermined direction of mounting (that is to say on the "inside" of the tyre; the corresponding sidewall commonly bearing the inscription "inside" and/or the opposite sidewall commonly bearing the inscription "outside") is made of a rubber compound that has better grip on dry ground. The axial extension of this portion changes as a function of the radial distance from the rolling surface of the unworn tread.

[0071] Figure 12 schematically depicts the crown of a tyre according to an embodiment of the invention. This tyre is designed to be mounted on a mounting rim of a wheel of a vehicle and has a predetermined direction of mounting on the vehicle. The tyre comprises a tread having a rolling surface 47 designed to come into contact with the ground (not depicted) when the tyre is rolling on a ground, and a tread portion designed to be worn off during the life of the tyre, this tread portion having a radial thickness T.

[0072] Figure 19 schematically illustrates how this radial thickness T, which may vary as a function of the axial position, is determined. For each axial position, one considers the radial depth PR (in mm) of the deepest incision that is found over the circumference of the tyre. The tyre depicted in figure 19 has a central groove (axial zone Z4) and a set of transversal incisions (axial zones Z2 and Z6). The maximum depth of the groove defines the value of PR in axial zone Z4, the maximum depth of the incisions in axial zones Z2 and Z6 the respective values of PR in those zones. The radial thickness T in those zones is defined to be PR (in mm) - 1.6. This is because there are regulations that require a tyre to have a minimum incision depth of 1.6 mm. If, for a given axial position, such as in axial zones Z3 and Z5, there is no incision, over the whole circumference of the tyre, but there are axial positions on both sides (axially) of the axial position under consideration where incisions are found, then the radial thickness at the axial position under consideration is defined to be the interpolated thickness of the closest axial positions on both sides where there are incisions. If, for a given axial position, such as in axial zones Z1 and Z7, there is no incision, over the whole circumference of the tyre, but there are axial positions axially inside the axial position under consideration where incisions are found (here axial zones Z2 and Z6, respectively), then the radial thickness at the axial position under consideration is defined to be identical to the thickness of the closest axial positions axially inside it where there are incisions. The resulting curve for the radial thickness T as a function of the axial position is drawn as dotted line 300.

[0073] Coming back to figure 12, the tread, when unworn, has an outer edge 45 and an inner edge 46, the outer edge 45 being situated on that side of the tyre which, when the tyre is mounted on the vehicle in said predetermined direction of mounting, faces toward the outside of the vehicle (see figure 6), the inner edge 46 being situated on that side of the tyre which, when the tyre is mounted on the vehicle in said predetermined direction of mounting, faces toward the vehicle (see figure 6). The axial distance between the outer edge 45 and the inner edge 46 defines the axial width L of the tread.

[0074] The tread comprises a first portion 411 made of a first rubber compound. The first portion 411 extends from a first axial boundary position B1 to a second axial boundary position B2, the axial distance of said first axial boundary position B1 from the inner edge 46 being greater than or equal to 95% of the of the axial width L of the tread.

[0075] The tread further comprises a second portion 412 axially adjacent to the first portion 411 and made of a second rubber compound. The second portion 412 extends from a third axial boundary position B3 to a fourth axial boundary position B4. In the embodiment of figure 12, the second axial boundary position B2 and the third axial boundary position B3 coincide for all values of DR, where DR is the radial distance from the rolling surface 47 of the unworn tread.

[0076] The tread further comprises a third portion 413 axially adjacent to the second portion 412 and made of a third rubber compound. The third portion 413 extends from a fifth axial boundary position B5 to a sixth axial boundary position B6. The axial distance between the sixth axial boundary position B6 and the outer edge 45 is equal to 83% of the axial width L of the tread for $DR = 0.2 \cdot T$. In the embodiment of figure 12, the fifth axial boundary position B5 and the fourth axial boundary position B4 coincide for all values of DR.

[0077] Finally, the tread comprises a fourth portion 414 axially adjacent to the third portion 413 and made of a fourth rubber compound. The fourth portion 414 extends from a seventh axial boundary position B7, which coincides with the sixth axial boundary position B6 for all values of DR, to an eighth axial boundary position B8. The axial distance of the eighth axial boundary position from the outer edge 45 is greater than or equal to 95% of the of the axial width L of the tread for all values of DR.

[0078] The first, second, third and fourth portions 411-414 extend over the entire circumference of the tyre and have an intersection with the rolling surface 47 when the tyre is new.

[0079] Generally speaking, in a tyre according to the invention, at least one of the following conditions (C1) and (C2) is met, wherein each condition in fact has four sub-conditions: (1) to (4) and (1') to (4'), respectively:

[0080] Condition (C1): (1) the first portion has, in any radial section, an axial width that decreases as a function of the radial distance DR from the rolling surface of the unworn tread, (2) the second axial boundary position B2 varying as a function of the radial distance DR [in more mathematical terms, B2 = B2(DR)], such that the axial distance between the second axial boundary position B2 and the outer edge 45 is greater than or equal to 20% and smaller than or equal to 40% of the axial width L of the tread for $DR = 0.2 \cdot T$ (indicated by dashed line Q2), and (3) greater than or equal to 10%

and smaller than or equal to 38% of the axial width L of the tread for DR = 0.8·T (indicated by dashed line Q8), provided that (4) the second axial boundary position B2 for DR = 0.2·T is axially inside by at least 2% of the axial width L of the tread with respect to the second axial boundary position B2 for DR = 0.8·T [in more mathematical terms, B2(0.2·T) - B2 (0.8·T) ≥ 0.02·L]. Sub-conditions (2) and (3) have been visualised in figure 12 by means of the double arrows A1 and A2. In order to satisfy sub-condition (2), the intersection of the second axial boundary position B2 and line Q2 has to lie on arrow A1; in order to satisfy sub-condition (3), the intersection of the second axial boundary position B2 and line Q8 has to lie on arrow A2.

[0081] Condition (C2): (1') the second portion has, in any radial section, an axial width that increases as a function of the radial distance DR from the rolling surface of the unworn tread, (2') the fourth axial boundary position B4 varying as a function of the radial distance DR [in more mathematical terms, B4 = B4(DR)], such that the axial distance between the fourth axial boundary position B4 and the outer edge is greater than or equal to 50% and smaller than or equal to 60% of the axial width L of the tread for DR = 0.2·T, and (3') greater than or equal to 52% and smaller than or equal to 70% of the axial width L of the tread for DR = 0.8·T, provided that (4') the fourth axial boundary position B4 for DR = 0.2·T is axially inside by at least 2% of the axial width L of the tread with respect to the fourth axial boundary position B4 for DR = 0.8·T [in more mathematical terms, B4(0.8·T) - B4(0.2·T) ≥ 0.02·L]. Sub-conditions (2') and (3') have been visualised in figure 12 by means of the double arrows A3 and A4. In order to satisfy sub-condition (2'), the intersection of the fourth axial boundary position B4 and line Q2 has to lie on arrow A3; in order to satisfy sub-condition (3'), the intersection of the fourth axial boundary position B4 and line Q8 has to lie on arrow A4.

[0082] Both conditions (C1) and (C2) are satisfied for the tyre of figure 12. The first portion 411 has, in any radial section, an axial width that decreases as a function of the radial distance DR from the rolling surface 47 of the unworn tread. The second axial boundary position B2 varies as a function of the radial distance DR, such that the axial distance between the second axial boundary position B2 and the outer edge 45 is equal to 30% of the axial width L of the tread for DR = 0.2·T, and equal to 24% of the axial width L of the tread for DR = 0.8·T. Thus the second axial boundary position B2 for DR = 0.2·T is axially inside by 6% of the axial width L of the tread with respect to the second axial boundary position B2 for DR = 0.8·T. Thereby, condition (C1) as defined above is satisfied in this tyre.

[0083] Moreover, the second portion 412 has, in any radial section, an axial width that increases as a function of the radial distance DR from the rolling surface 47 of the unworn tread. The fourth axial boundary position B4 varies as a function of the radial distance DR, such that the axial distance between the fourth axial boundary position B4 and the outer edge 45 is equal to 58% of the axial width L of the tread for DR = 0.2·T, and equal to 66% of the axial width L of the tread for DR = 0.8·T. Thus the fourth axial boundary position B4 for DR = 0.2·T is axially inside by 8% of the axial width L of the tread with respect to the fourth axial boundary position B4 for DR = 0.8·T. Thereby, condition (C2) as defined above is also satisfied in this tyre.

[0084] Figures 13 to 16 show four two more embodiments of a crown of a tyre according to embodiments of the invention. Table I lists the axial distances between the various axial boundary positions B2 to B7 and the outer edge 45 (as percents of the axial width L of the tread) for the embodiments of figures 12 to 14.

Table I

	DR	Figure 12	Figure 13	Figure 14
B2 = B3	0.2·T	30%	27%	27%
	0.8·T	24%	24%	24%
B4 = B5	0.2·T	58%	59%	59%
	0.8·T	66%	67%	64%
B6 = B7	0.2·T	83%	81%	85%
	0.8·T	78%	74%	91%

[0085] The crown of the tyre depicted in figure 13 is similar to the crown depicted in figure 12 and has similar advantages; the essential difference consists in the fact that portion 413 disappears before the tread is completely worn off. So when the tread is worn off most of the rolling surface is made of rubber compounds that have better grip on wet ground.

[0086] The crown of the tyre depicted in figure 14 is different in that the axial width of portion 413 increases when the tyre wears off. Its advantage over the crown of figure 13 is that the risk of portion 413 being detached from portions 412 and 414 is reduced.

[0087] When the crown comprises grooves (as most crowns indeed do ; the tyre of figure 12 has been drawn without grooves for the sake of clarity only) and when adjacent portions are separated by such grooves, then the axial boundary positions of adjacent portions do not coincide any more. This is illustrated in figures 15 and 16.

[0088] Figure 15 shows a tread where a groove 201 is provided axially between the first portion 411 and the second portion 412. Therefore, condition (C1) is not fulfilled. However, condition (C2) is still satisfied by the fourth axial boundary position B4 (which coincides with the fifth axial boundary position B5).

[0089] Figure 16 shows the converse situation where condition (C1) is satisfied by the second axial boundary position B2 (which coincides with the third axial boundary position B3) whereas condition (C2) is not fulfilled because a groove 202 is provided axially between the second portion 412 and the third portion 413.

[0090] When the tread of a tyre according to an embodiment of the invention is obtained by extrusion, the boundaries between adjacent portions will, as a rule, be rectilinear in radial section, such as in figures 12 to 16. This is, however, not an essential feature of a tyre according to the invention. As shown in figure 17, it is possible to change the axial width of some or all the portions stepwise. This is particularly easy to obtain when the tread is produced by superposing rubber strips. It is also possible to arrange the portions so that the boundaries between adjacent portions have more complex shapes in radial section, as portion 412 in figure 17. The particular shape of portion 412 in this embodiment results in a sudden increase of the wet grip when the tyre wear is advanced.

[0091] In a tyre according to the invention, the first rubber compound and the third rubber compound are compounds that have good grip on dry ground. They contain at least one elastomer and at least one reinforcing filler containing a carbon black, the carbon black representing a percentage PN1 greater than or equal to 50% and less than or equal to 100% of the weight of all of the reinforcing filler. The second rubber compound and the fourth rubber compound contain at least one elastomer and at least one reinforcing filler, possibly including a carbon black, the carbon black representing a percentage PN2 greater than or equal to 0% and less than or equal to 50% of the weight of all of the reinforcing filler.

[0092] Moreover, the first rubber compound and the third rubber compound have a value for tanδ at 0°C, at a stress of 0.7 MPa, that is lower than that of the second rubber compound and the fourth rubber compound.

[0093] Table II gives, by way of example, the composition of rubber compounds that can be used in tyres according to the invention. The composition is given in pce ("per cent elastomer") that is to say in parts by weight for 100 parts by weight of elastomer.

Table II

	Compound with better grip on dry ground	Compound with better grip on wet ground
SBR Elastomer [1]	100	100
N 234 [2]	100	-
Silica	-	100
TESPT coupling agent (Degussa Si 69)	-	8.0
Plasticizer [3]	50	50
Anti-ozone wax C32 ST	1.5	1.5
Antioxidant (6PPD) [4]	2.0	2.0
Diphenylguanidine (DPG)	-	1.7
ZnO	1.8	1.8
Stearic acid	2.0	2.0
Sulphur	1.3	1.3
Accelerator (CBS)	1.95	1.95

[0094] Notes for Table II:

[1] SSBR with 40% styrene, 48% 1-4 trans polybutadiene groups

[2] Carbon black series 230 (ASTM)

[3] TDAE ("treated distillate aromatic extract") oil

[4] N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine

[0095] The rubber compounds are preferably based on at least one diene elastomer, one reinforcing filler and a crosslinking system.

[0096] What is meant by a "diene" elastomer (or interchangeably rubber) is, in the known way, an elastomer derived at least in part from (i.e. a homopolymer or a copolymer of) diene monomers, that is to say monomers bearing two carbon-carbon double bonds, conjugated or otherwise. The diene elastomer used is preferably chosen from the group consisting of polybutadienes (BR), natural rubber (NR), synthetic polyisoprenes (IR), styrene butadiene copolymers (SBR), isoprene-butadiene copolymers (BIR), isoprene-styrene copolymers (SIR), butadiene-styrene-isoprene copolymers (SBIR) and blends of these elastomers.

[0097] One preferred embodiment is to use an "isoprene" elastomer, that is to say a homopolymer or copolymer of isoprene, or in other words, a diene elastomer chosen from the group consisting of natural rubber (NR), synthetic polyisoprenes (IR), the various copolymers of isoprene and blends of these elastomers.

[0098] The isoprene elastomer is preferably natural rubber or a synthetic polyisoprene of the cis-1,4 type. Of these synthetic polyisoprenes, use is preferably made of polyisoprenes that have a cis-1,4 bond content (mol%) in excess of 90%, or more preferably still, in excess of 98%. According to other preferred embodiments, the diene elastomer may consist, in full or in part, of another diene elastomer such as, for example, an SBR (E-SBR or S-SBR) elastomer used in combination or otherwise with another elastomer for example of the BR type.

[0099] The rubber composition may also contain all or some of the additives conventionally employed in the rubber matrices used for the manufacture of tyres, such as, for example, reinforcing fillers such as carbon black or inorganic fillers such silica, coupling agents for inorganic fillers, anti-aging agents, antioxidants, plasticizers or extender oils, whether the latter are of aromatic or non-aromatic nature (notably oils that are only very slightly aromatic or non-aromatic, for example of the naphthene or paraffin type, with a high or preferably low viscosity, MES or TDAE oils, plasticizing resins with a high Tg in excess of 30°C), agents that improve the processability of the compositions in the green state, tackifying resins, a crosslinking system based either on sulphur or sulphur donors and/or peroxides, accelerators, vulcanization activators or retarders, anti-reversion agents, methylene acceptors and donors such as, for example, HMT (hexamethylenetetramine) or H3M (hexamethoxymethylmelamine), reinforcing resins (such as resorcinol or bismaleimide), known adhesion promoting systems of the metal salt type, for example, notably cobalt or nickel salts.

[0100] The compositions are manufactured in appropriate mills, using two successive phases of preparation well known to those skilled in the art, namely a first phase of thermomechanical work or kneading (the so-called "non-productive" phase) at high temperature, up to a maximum temperature of between 110°C and 190°C, preferably between 130°C and 180°C, followed by a second phase of mechanical work (the so-called "productive" phase) down to a lower temperature, typically of less than 110°C, during which finishing stage the crosslinking system is incorporated.

[0101] By way of example, the non-productive phase is conducted in a single thermomechanical step lasting a few minutes (for example between 2 and 10 min) during which all the required basic ingredients and other additives, apart from the crosslinking or vulcanizing system, are introduced into an appropriate mixer such as a conventional internal mixer. Once the compound thus obtained has cooled, the vulcanizing system is then incorporated with it in an external mixer such as an open mill kept at a low temperature (for example between 30°C and 100°C). This is then blended (productive phase) for a few minutes (for example for between 5 and 15 min).

[0102] Vulcanizing (or curing) may be performed in the known way at a temperature generally between 130°C and 200°C, preferably under pressure, for a sufficient length of time which may vary, for example, between 5 and 90 min depending in particular on the curing temperature, on the vulcanizing system adopted and on the vulcanization dynamics of the composition considered.

[0103] Table III gives the properties of the rubber compounds the composition of which is given in Table I

Table III

	Compound with better grip on dry ground	Compound with better grip on wet ground
tanδ at 0°C, at 0.7 MPa	0.76	0.88
tanδ at 10°C, at 0.7 MPa	0.69	0.58

[0104] These properties are measured with a viscoanalyser (Metravib VA4000), in accordance with standard ASTM D 5992-96. The response of a test specimen of vulcanized composition (a cylindrical test specimen 4 mm thick and 400 mm^2 in section) subjected to simple alternating sinusoidal shear stresses at a frequency of 10 Hz, during a temperature sweep between 0° and 100°C, under a fixed stress of 0.7 MPa, is recorded, particularly the value of tanδ observed at 0°C and the values of tanδ observed at 10°C.

[0105] It will be recalled that, as is well known to those skilled in the art, the value of tanδ at 0°C is representative of the potential to grip on wet ground: the higher tanδ at 0°C, the better the grip. The values of tanδ at temperatures higher than 10°C are representative of the hysteresis of the material and of the potential to grip on dry ground.

[0106] To return to the compounds the composition of which is given in Table II, it may be seen that the second composition has a value of tanδ at 0°C (imposed stress 0.7 MPa) that is higher by comparison with the first composition, indicating that its grip on wet ground will be superior; and has a value of tanδ at 10°C that is lower by comparison with the first composition, indicating that the grip on dry ground would be inferior.

[0107] Tests were carried out using a Porsche 997 fitted with Pilot Super Sport tyres, size 245/35 R20 (on the front) and 295/30 R20 (on the rear). A tyre equipped with a tread as depicted in Figure 14 was compared against a reference tyre equipped with a tread as depicted in Figure 7. The rubber compounds of Table I were used. The tyres according to the invention saved an average of 1 second per lap (on the Nardo (Italy) "handling" circuit with a circuit length of 6.2 km) on dry ground, at the expense of just 0.2 seconds per lap on wet ground. These improved times were backed by the subjective assessment of the drivers who reported better grip on dry ground and substantially unchanged grip on wet ground. The trials were repeated at a wear level close to 80% : significantly better grip on wet ground was reported. The invention therefore provides a better compromise between grip on dry ground and grip on wet ground at all levels of wear.

Claims

1. Tyre (10) designed to be mounted on a mounting rim of a wheel of a vehicle (200) and having a predetermined direction of mounting on the vehicle, wherein the tyre comprises a tread (40) having a rolling surface (47) designed to come into contact with a ground (3) when the tyre is rolling on the ground, and a tread portion designed to be worn off during the life of the tyre, this tread portion having a radial thickness T, wherein the tread, when unworn, has an outer edge (45) and an inner edge (46), the outer edge being situated on that side of the tyre which, when the tyre is mounted on the vehicle in said predetermined direction of mounting, faces toward the outside of the vehicle, the inner edge being situated on that side of the tyre which, when the tyre is mounted on the vehicle in said predetermined direction of mounting, faces toward the vehicle, the axial distance between the outer edge and the inner edge defining the axial width L of the tread, the tread comprising, in any radial section:

a first portion (411) made of at least one first rubber compound, wherein the first portion extends from a first axial boundary position (B1) to a second axial boundary position (B2), the axial distance of said first axial boundary position from the inner edge being greater than or equal to 95% of the of the axial width L of the tread,
a second portion (412) axially adjacent to the first portion and made of at least one second rubber compound, wherein the second portion extends from a third axial boundary position (B3) to a fourth axial boundary position (B4),
a third portion (413) axially adjacent to the second portion and made of at least one third rubber compound, the third portion extending from a fifth axial boundary position (B5) to a sixth axial boundary position (B6), wherein the axial distance between said sixth axial boundary position and the outer edge is greater than or equal to 80% and smaller than or equal to 90% of the axial width L of the tread for DR = 0.2·T, where DR is the radial distance from the rolling surface of the unworn tread, and
a fourth portion (414) axially adjacent to the third portion and made of at least one fourth rubber compound, the fourth portion extending from a seventh axial boundary position (B7) to an eighth axial boundary position (B8), the axial distance of said eighth axial boundary position from the outer edge being greater than or equal to 95% of the of the axial width L of the tread,
wherein said first, second, third and fourth portions extend over the entire circumference of the tyre and have an intersection with the rolling surface when the tyre is new or, at the latest, when the tread wear has reached 10%,
wherein said at least one first rubber compound and said at least one third rubber compound contain at least one elastomer and at least one reinforcing filler containing a carbon black, the carbon black representing a percentage PN1 greater than or equal to 50% and less than or equal to 100% of the weight of all of the reinforcing filler, and wherein said at least one second rubber compound and said at least one fourth rubber compound contain at least one elastomer and at least one reinforcing filler, possibly including a carbon black, the carbon black representing a percentage PN2 greater than or equal to 0% and less than or equal to 50% of the weight of all of the reinforcing filler,
wherein said at least one first rubber compound and said at least one third rubber compound have a value for tanδ at 0°C, at a stress of 0.7 MPa, that is lower than that of said at least one second rubber compound and said at least one fourth rubber compound, and wherein at least one of the following conditions (C1) and (C2) is met:

(C1) the first portion has, in any radial section, an axial width that decreases as a function of the radial distance DR from the rolling surface of the unworn tread, the second axial boundary position varying as a function of the radial distance DR, such that the axial distance between the second axial boundary position and the outer edge is greater than or equal to 20% and smaller than or equal to 40% of the axial width L of the tread for DR = 0.2·T, and greater than or equal to 10% and smaller than or equal to 38% of the axial width L of the tread for DR = 0.8·T, provided that the second axial boundary position for DR = 0.2·T is axially inside by at least 2% of the axial width L of the tread with respect to the second axial boundary position for DR = 0.8·T;

(C2) the second portion has, in any radial section, an axial width that increases as a function of the radial distance DR from the rolling surface of the unworn tread, the fourth axial boundary position varying as a function of the radial distance DR, such that the axial distance between the fourth axial boundary position and the outer edge is greater than or equal to 50% and smaller than or equal to 60% of the axial width L of the tread for DR = 0.2·T, and greater than or equal to 52% and smaller than or equal to 70% of the axial width L of the tread for DR = 0.8·T, provided that the fourth axial boundary position for DR = 0.2·T is axially inside by at least 2% of the axial width L of the tread with respect to the fourth axial boundary position for DR = 0.8·T.

2. Tyre according to Claim 1, wherein both conditions (C1) and (C2) are met.

3. Tyre according to Claim 1 or 2, wherein said portions (411, 412, 413, 414) made of said at least one first, second, third and fourth rubber compounds all have an intersection with the rolling surface when the tyre is new.

4. Tyre according to any one of Claims 1 to 3, wherein for at least some values of the radial distance DR said second axial boundary position and said third axial boundary position coincide, and/or said fourth axial boundary position and said fifth axial boundary position coincide, and/or said sixth axial boundary position and said seventh axial boundary position coincide.

5. Tyre according to any one of Claims 1 to 3, wherein for at least some values of the radial distance DR said second axial boundary position and said third axial boundary position delimit an incision in the tread, and/or said fourth axial boundary position and said fifth axial boundary position delimit an incision in the tread, and/or said sixth axial boundary position and said seventh axial boundary position delimit an incision in the tread.

6. Tyre according to any one of Claims 1 to 5, wherein said at least one third rubber compound is identical to said at least one first rubber compound and wherein said at least one fourth rubber compound is identical to said at least one second rubber compound.

7. Tyre according to any one of Claims 1 to 6, wherein said at least one first rubber compound and said at least one third rubber compound have a value for tanδ at 10°C, at a stress of 0.7 MPa, that is higher than that of said at least one second rubber compound and said at least one fourth rubber compound.

8. Tyre according to any one of Claims 1 to 7, wherein the difference between the value of tanδ for said at least one first rubber compound and said at least one second rubber compound is greater than or equal to 0.05, wherein the difference between the value of tanδ for said at least one second rubber compound and said at least one third rubber compound is greater than or equal to 0.05, and wherein the difference between the value of tanδ for said at least one third rubber compound and said at least one fourth rubber compound is also greater than or equal to 0.05.

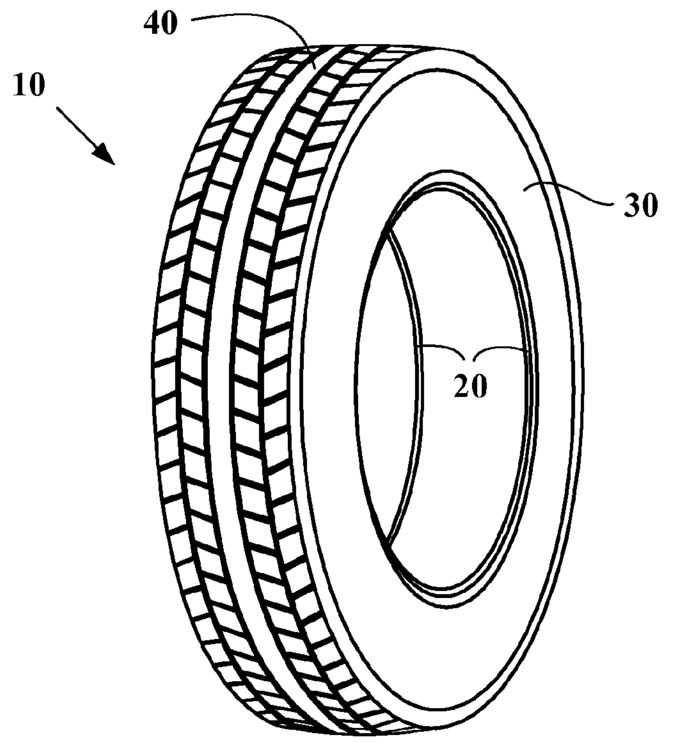


FIG. 1
(PRIOR ART)

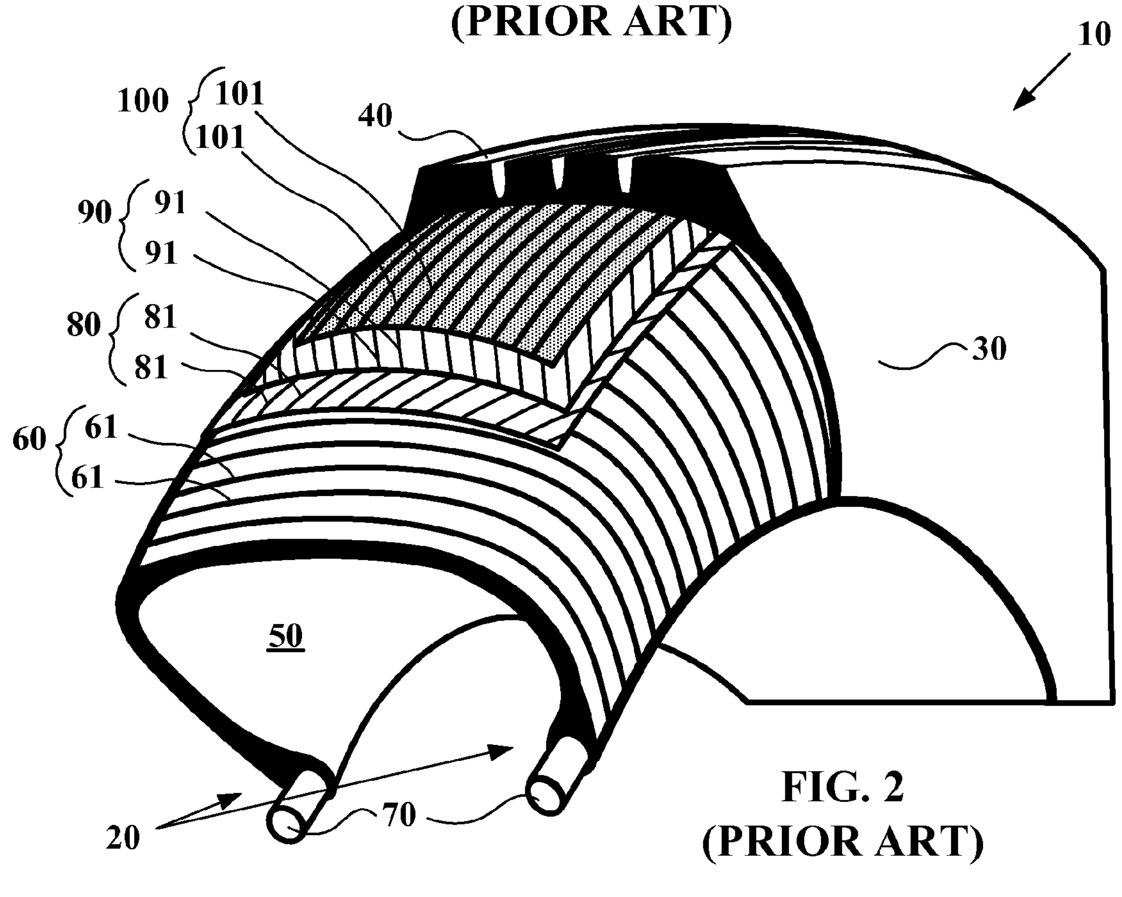


FIG. 2
(PRIOR ART)

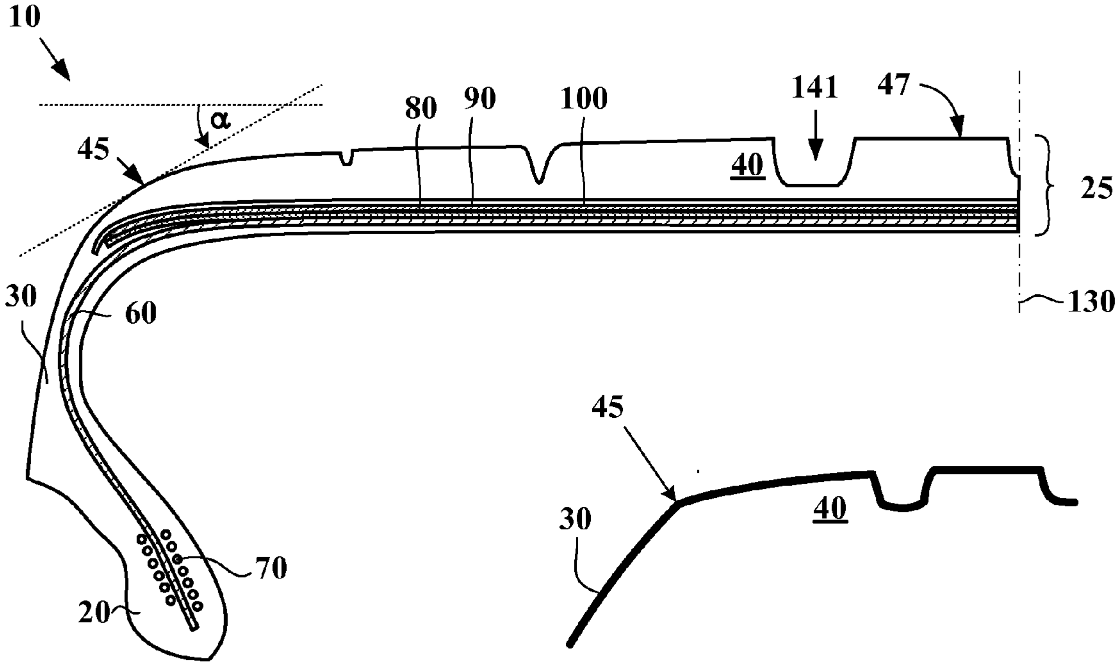


FIG. 4

FIG. 3
(PRIOR ART)

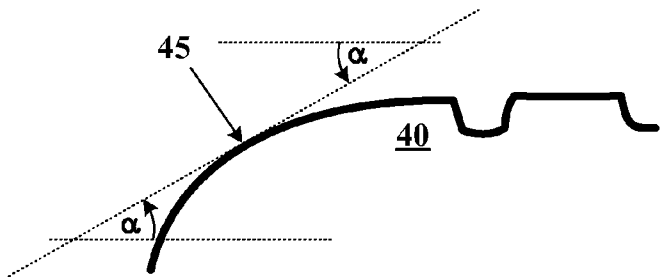


FIG. 5

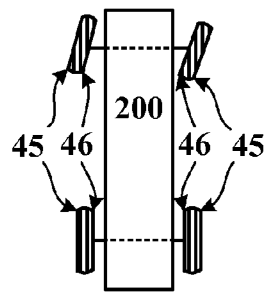


FIG. 6

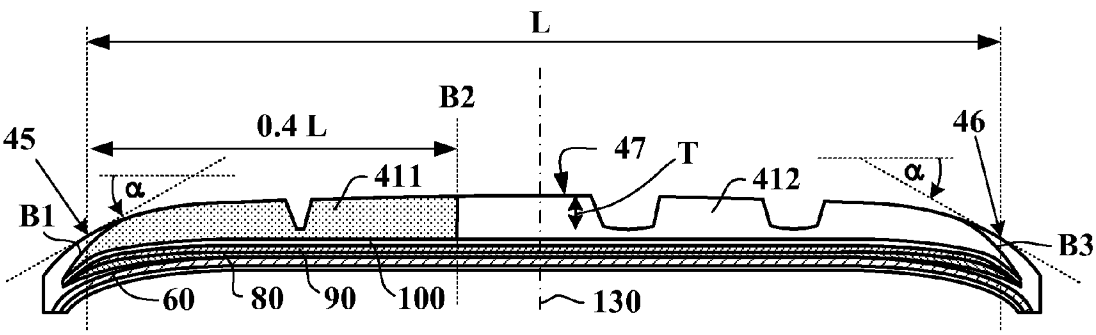
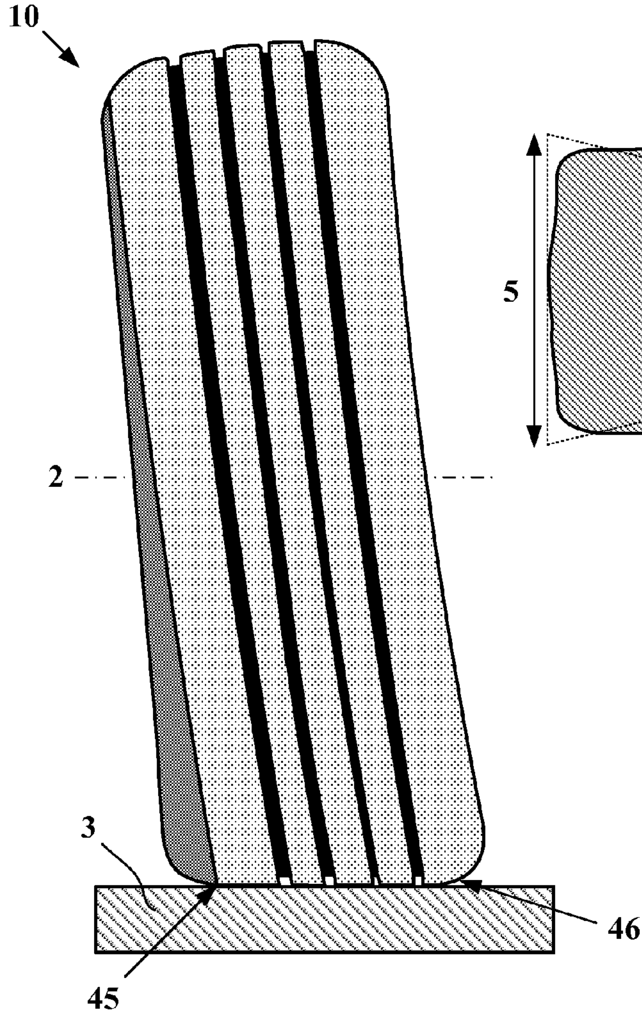


FIG. 7 (PRIOR ART)



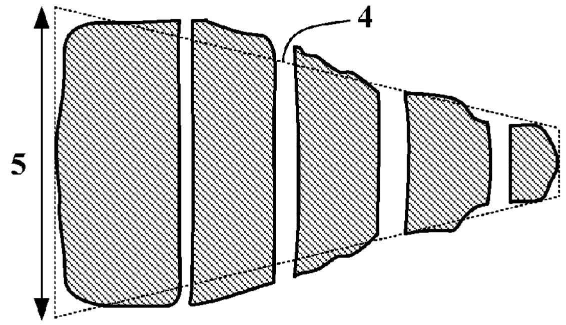
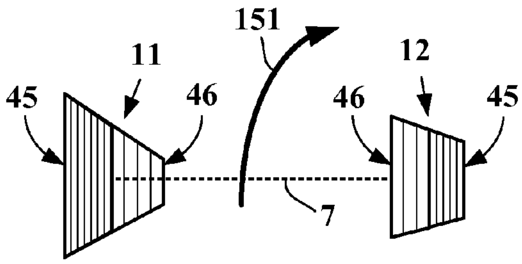


FIG. 9

FIG. 8



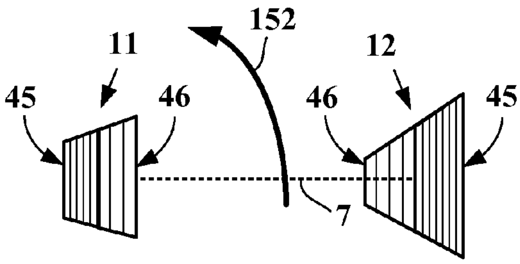


FIG. 10

FIG. 11

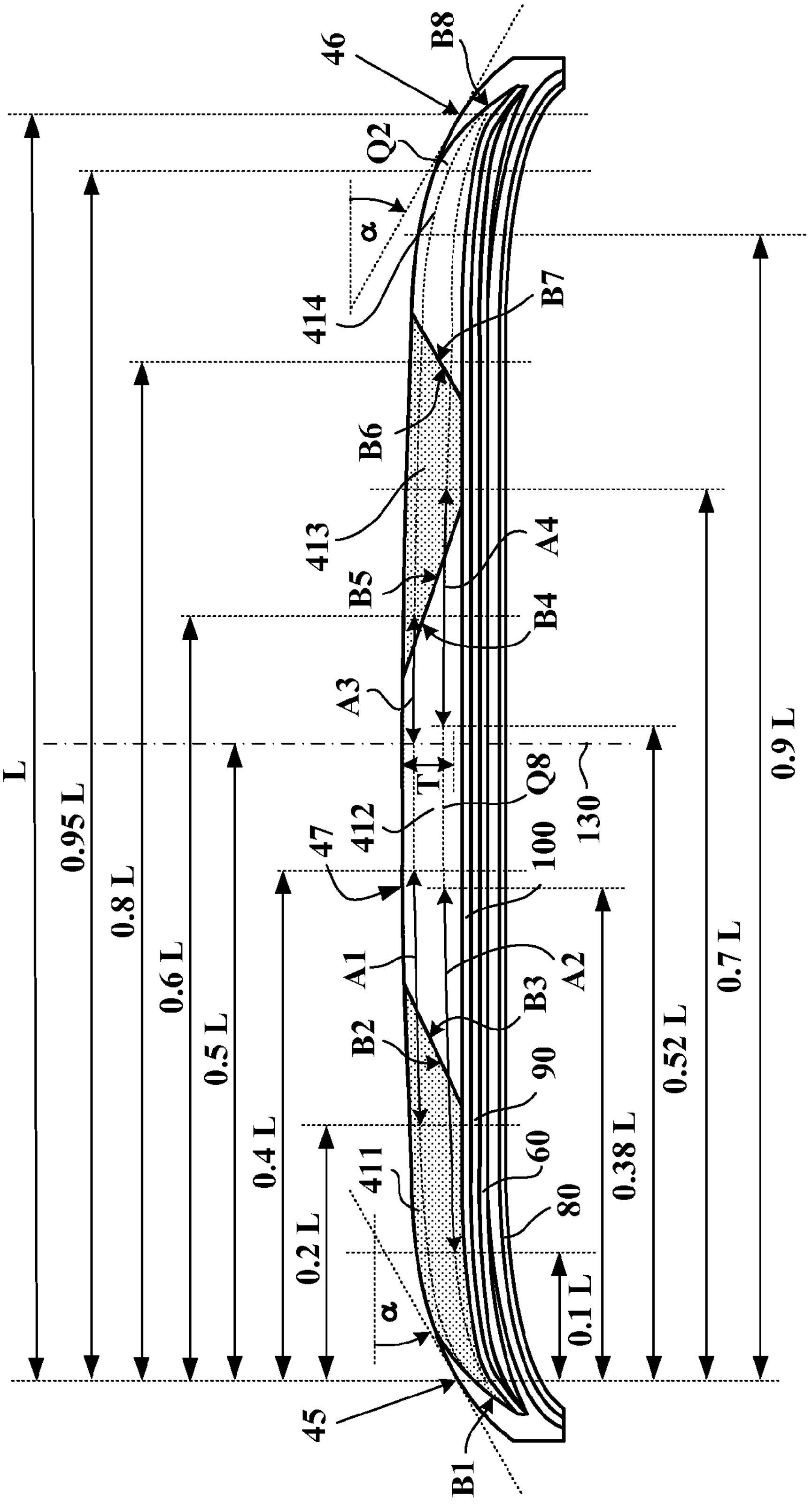

L
0.95 L
0.8 L
0.6 L
0.5 L
0.4 L
0.2 L
0.1 L
0.38 L
0.52 L
0.7 L
0.9 L
45
46
47
B1
B2
B3
B4
B5
B6
B7
B8
Q2
Q8
α
α
411
412
413
414
A1
A2
A3
A4
T
60
80
90
100
130

FIG. 12

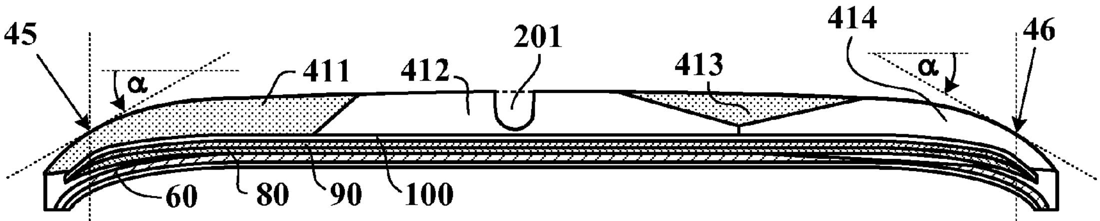


FIG. 13

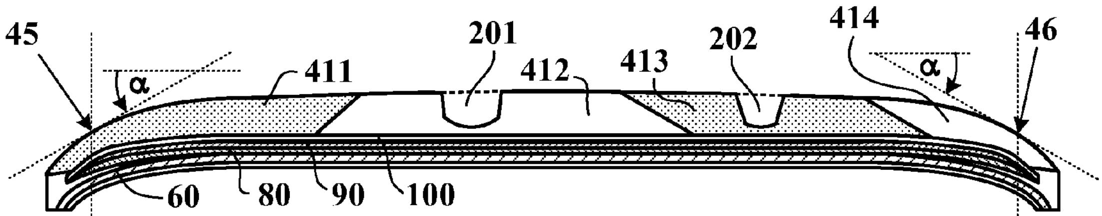


FIG. 14

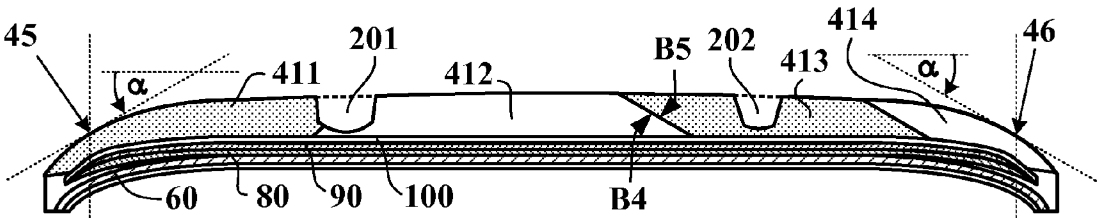


FIG. 15

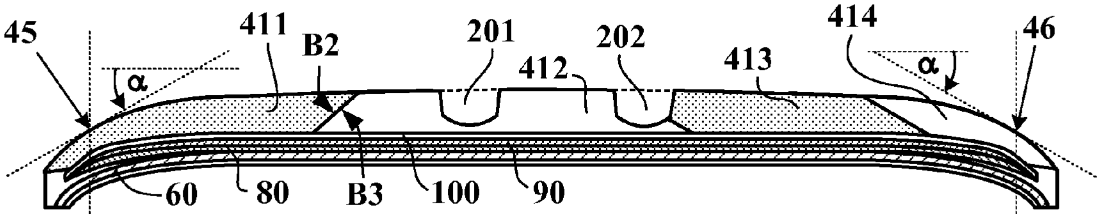


FIG. 16

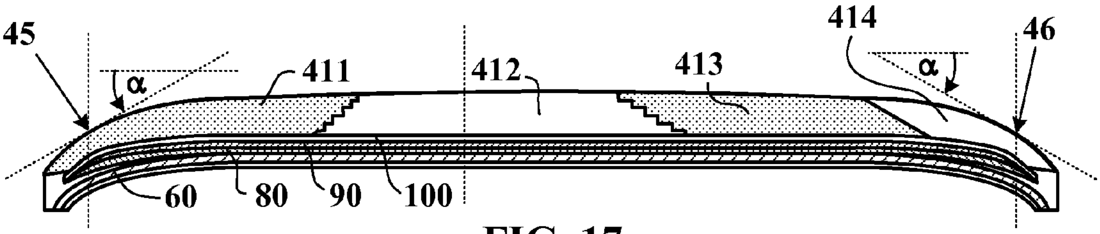


FIG. 17

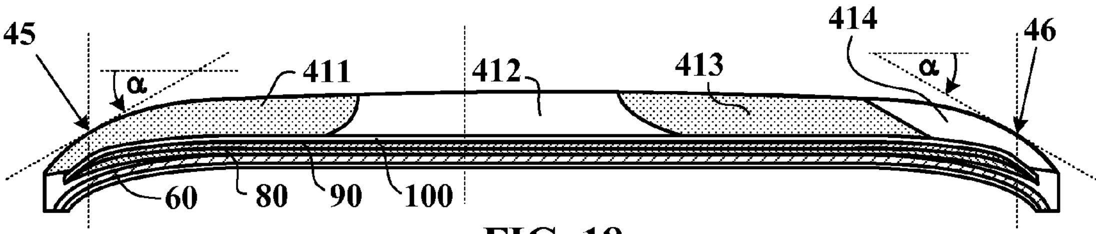


FIG. 18

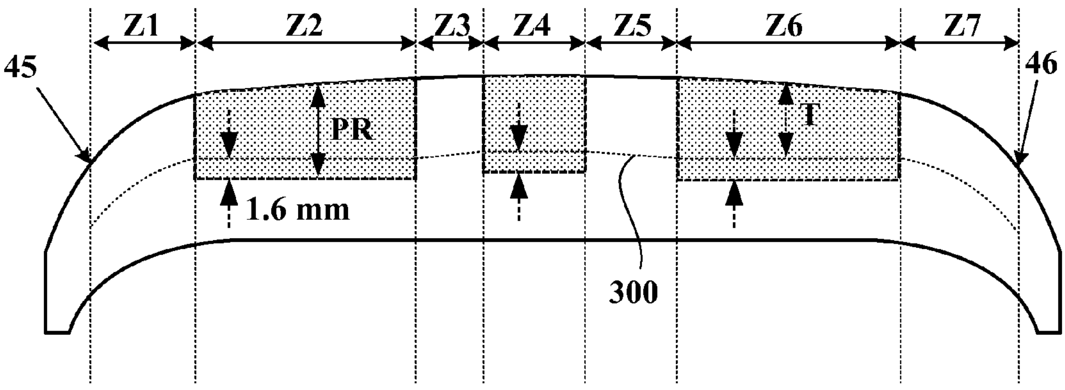


FIG. 19

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EUROPEAN SEARCH REPORT

Application Number
EP 11 30 5801

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	EP 1 561 605 A2 (GOODYEAR TIRE & RUBBER [US]) 10 August 2005 (2005-08-10) * paragraphs [0049] - [0058]; figure 1B * -----	1	INV. B60C1/00
A	JP 3 025003 A (TOYO TIRE & RUBBER CO) 1 February 1991 (1991-02-01) * abstract; figure 2 * -----	1	
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			B60C

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	26 October 2011	Buergo, Javier

CATEGORY OF CITED DOCUMENTS

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26-10-2011

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